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Prairiegrass–Brassica Hybrid Swards for Autumn Dry Matter Production

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ABSTRACT

Stockpiling herbage can redistribute nutrient availability and supplement quantity for livestock, depending on production objectives. Brassicas (*Brassica* spp.) and improved prairiegrass (*Bromus catharticus* Vahl.) cultivars are adapted to growing conditions occurring in the Appalachian region and provide nutritionally valuable herbage in autumn; however, highly digestible brassica herbage may require supplementation with a fibrous companion species for efficient rumen microbe function and nutrient use by grazers. A prairiegrass–brassica hybrid [*B. rapa* L. × *B. rapa* subsp. *pekinensis* (Lour.) Hanelt.] mixture and pure stands of each were established to determine productivity and nutritive value of stockpiled stands in autumn. Field plots were established in late June of 2003 and 2004, and clipping began 74 and 63 d after planting, respectively. Prairiegrass co-established with brassica hybrid and could be harvested in the establishment year. Sown species and year interacted to influence stand composition, dry matter productivity, and nutritive value. Dry conditions occurred shortly after planting in 2003 and slowed brassica hybrid establishment and productivity. Total dry matter varied for monospecific and mixed stands of prairiegrass and brassica hybrid each year, as did distribution during the season. Nutritive value varied with years and met or exceeded values suggested for efficient rumen microbe function. Herbage growth continued for about 80 d after the first clip in early September for all sward types and demonstrated the compatibility of co-seeded prairiegrass and brassica hybrid as well as the suitability of the mixture to provide adequate herbage mass and nutritive value when stockpiled in autumn.

Herbage growth is slow in autumn and ceases during winter in much of the central Appalachian region of the eastern USA, creating a potential shortfall of herbage in forage-based livestock production systems. Stockpiling, or accumulating herbage for later use, can supplement quantity, redistribute availability, reduce the need for purchased feed, and help meet livestock nutrient requirements when gaps occur. Important considerations when designing stockpile components of forage–livestock systems include dry matter production and nutritive value needs. Careful management is required to achieve the desired herbage mass and nutritive value. Trade-offs between herbage yield and nutritive value determine when stockpiling should begin and accumulated herbage used (Matches and Burns, 1995).

Plants that resist the destructive effects of weather (e.g., frost and wind) and retain herbage nutritive value in late autumn or early winter {e.g., tall fescue [*Lolium arundinaceum* Schreb. Darbyshire (formerly *Festuca arundinacea* Schreb.)} are ideal for late-season stockpiling. Much of what is known about autumn stockpiled herbage focuses on tall fescue with tough, resilient leaves and orchardgrass (*Dactylis glomerata* L.), which is common in pastures throughout the Appalachian region (Baker et al., 1988).

Alternative species that could be used for autumn stockpile include grasses with strong late-season production (e.g., *Bromus* spp.). For example, 'Matua' prairiegrass (*Bromus willdenowii* Kunth.) grew vigorously during autumn in central Appalachia (Belesky and Stout, 1994), but persistence was compromised by susceptibility to diseases. A stockpiled mixture of smooth bromegrass (*Bromus inermis* L.) and red clover (*Trifolium pratense* L.) was comparable to a mixture of tall fescue and alfalfa (*Medicago sativa* L.) in terms of productivity, nutritive value, and livestock performance (Hitz and Russell, 1998). New prairiegrass (*Bromus catharticus* Vahl.) cultivars with disease resistance, upright growth habit ('Dixon') (Rumball and Miller, 2003a), or ability to tolerate cold weather ('Lakota') (Rumball and Miller, 2003b) are suited to growing conditions in many parts of the USA. The new prairiegrass cultivars could prove to be useful components of systems requiring high quality herbage in autumn (Belesky and Cassida, 2004; Belesky and Ruckle, 2005).

Forage brassicas are fast-growing, cold-tolerant annuals that can provide herbage mass and quality needed to sustain livestock late in the year. Brassicas planted in midsummer are productive in autumn and retain high nutrient concentrations when stockpiled (Guillard et al., 1988; Cassida et al., 1995). The high soluble nutrient content of brassica species should be supplemented with a source of fiber for efficient rumen function and nutrient use (Cassida et al., 1994). One means of achieving this in pasture would be to establish brassica along with a companion grass. Information demonstrating the compatibility of grass–brassica mixtures sown at the same time is scarce. Our objective was to determine the seasonal pattern of herbage production and nutritive value of a prairiegrass–brassica hybrid mixture sown in midseason and stockpiled in autumn.

MATERIALS AND METHODS

Plots were established on an upland site of the Allegheny Plateau in southern West Virginia (37°46′ N, 81°00′ W; 870 m elevation above sea level). Soil was a Clymer series, channery loam (coarse-loamy, siliceous, active, mesic Typic Hapludult) on a hilltop site with <5% slope. Two glyphosate [*N*-(phosphono-methyl) glycine] applications (2.5 kg a.i. ha^{-1} each) and tillage eliminated existing cool- and warm-season

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Abbreviations: CP, crude protein; DAP, days after planting; DM, dry matter; RNY, relative nutrient yield; RY, relative yield; RYM, relative yield of mixture; TDN, total digestible nutrients; TNC, total nonstructural carbohydrate.

grasses. Soil fertility supplied moderate amounts of P (about 15 kg ha^{-1}) and ample K (about 250 kg ha^{-1}), at an initial pH of 7.03 in the surface 15 cm of soil.

Plots were sown 30 June 2003 and on an adjacent site on 29 June 2004 to Dixon prairiegrass, 'Tyfon' brassica hybrid [turnip (*Brassica campestris* var. *rapa* L.)–Chinese cabbage (*B. pekinensis* (Lour.) Rupr.)], or a mixture with both species. Main plots (3 by 9 m) were sward type (pure or mixed) in replicated (three) blocks with main plots divided to accommodate seven 1- by 3-m harvest strips. Stands were broadcast or no-till seeded (Tye[1] pasture seeder) to prairiegrass (45 kg seed ha^{-1}), brassica hybrid (9 kg Tyfon seed ha^{-1}), and the mix at 45 kg prairiegrass seed ha^{-1} and 5 kg Tyfon seed ha^{-1}. The area was cultipacked after seeding to improve seed-to-soil contact. About 150 kg N ha^{-1} as 19–19–19 fertilizer was applied to each plot in a split application with 75 kg of N at planting and 75 kg of N after the first clipping of a particular strip.

Clipping began 74 d after planting (DAP) in 2003 and 65 DAP in 2004. A new strip was cut from standing herbage at 14-d intervals throughout autumn each year. Each yield strip was harvested with a collection-bag-equipped, rotary mower adjusted to allow a 100-mm residue height. Sampled areas (yield strips) were assigned at random within a plot at the first harvest. Herbage was dried at 60°C in a forced-air oven, weighed for dry matter (DM) estimation, and ground in a cyclone mill. The botanical composition of each strip scheduled for harvest was determined before clipping. Botanical composition was determined visually using a point–intercept method (Warren-Wilson, 1959).

Nitrogen was determined by combustion of dry plant tissue (Carlo Erba EA 1108 CHNSO analyzer, Fisons Instruments, Beverly, MA) and expressed as crude protein (CP; g N kg^{-1} × 6.25). Total nonstructural carbohydrates (TNC) were determined by an autoanalyzer (Alpkem RFA 300, Astoria-Pacific, Int., Clackamas, OR) procedure. Computations for estimates of nutritive value, presented as total digestible nutrients (TDN), included TNC and CP (Belesky et al., 2005) where:

$$\mathrm{TDN{:}CP} = 2.19\,(\mathrm{TNC{:}CP}) + 3.99 \qquad [1]$$

Calculations

Relative yields (RY) for prairiegrass and brassica hybrid were computed according to Fowler (1982) and relative yield mixture (RYM) computed according to Wilson (1988). The RY of each target species, either prairiegrass or brassica hybrid, was computed as:

$$\text{Relative yield prairiegrass } (\mathrm{RY_P}) = Y_{\mathrm{PB}}/(P_{\mathrm{p}} Y_{\mathrm{p}}) \qquad [2]$$

$$\text{Relative yield brassica hybrid } (\mathrm{RY_B}) = Y_{\mathrm{BP}}/(P_{\mathrm{B}} Y_{\mathrm{B}}) \qquad [3]$$

where Y_P and Y_B are yields of prairiegrass and brassica hybrid, respectively, for stands of each at each harvest date; P_P and P_B are the relative proportions of prairiegrass and brassica hybrid, respectively, in mixtures at each harvest date; and Y_{PB} represents yield of prairiegrass in presence of brassica hybrid, and Y_{BP} is yield of brassica hybrid in presence of prairiegrass.

Relative yield mixture was computed as:

$$\mathrm{RYM} = (\mathrm{RY_{PB}} + \mathrm{RY_{BP}})/P_{\mathrm{P}} Y_{\mathrm{P}} + P_{\mathrm{B}} Y_{\mathrm{B}} \qquad [4]$$

Relative nutrient yield (RNY) and relative nutrient yield mixture (RNYM) for prairiegrass and brassica hybrid were calculated in the same manner as relative yield. The RNY was computed as:

$$\mathrm{RNY} = [(\mathrm{TDN}/100) \times \mathrm{DM}\ (\mathrm{kg\ ha^{-1}})] \qquad [5]$$

Cumulative yield data were fit to the Gompertz equation to compute inflection points representing the instantaneous growth rate (Draper and Smith, 1981):

$$\omega = \alpha \exp\,[-\beta \exp(-kt)] \qquad [6]$$

where ω = herbage mass (kg DM ha^{-1}), t = day of year, and α (asymptotic yield), β (time function), and k (dimensionless) are calculated regression parameters.

The experiment was established as a split plot with plant stand and planting methods as main plots and harvest dates within each as the split plot. Data for cumulative DM yield (seeded species), components of botanical composition, CP, and TNC were analyzed as a randomized complete block design using PROC MIXED procedures in SAS (Littell et al., 1996). Data for the third clip (92 DAP) of 2004 are not included in the analysis. Seeded species, planting method, and harvest dates were considered fixed effects and replication random in the model. Years were analyzed separately within the mixed model because χ^2 test indicated heterogeneity of variance.

RESULTS AND DISCUSSION

Growing Conditions

Maximum and minimum temperatures were somewhat below the 30-yr mean in 2003 and at or above the means in 2004 (Fig. 1). Precipitation varied from month to month in each year, at times exceeding and falling below the 30-yr mean for a given month (Fig. 1). The greatest disparity in precipitation between years occurred immediately after planting in July. The relatively small amount of precipitation in July of 2003 and ample amount in July 2004 probably influenced stand establishment and consequently sward composition and total herbage productivity in the respective growing seasons. Gerrish and Sanderson (2000) reported similar fluctuation in total productivity with varying precipitation for swards differing in floristic complexity. Total precipitation (610 mm in 2003 and 630 mm in 2004) might be less of a concern than when events occurred and the amount occurring at each event.

Botanical Composition

Influences of planting method and sown species on floristic composition of stands varied and in some cases interacted (Table 1). Stands of prairiegrass or brassica hybrid sown in 2003 had as much as 75% other taxa [white clover (*Trifolium repens* L.), plantain (*Plantago* spp.), *Poa* spp., tall fescue, and orchardgrass], regardless of planting method (Fig. 2). In 2004, monospecific stands were composed primarily of sown species with very few weeds. Prairiegrass increased as a fraction of the stand at each successive clip in 2004 as the presence of warm-season grasses (primarily crabgrass, *Digitaria* spp.) declined. Prairiegrass represented a greater proportion of mixed stands of prairiegrass–brassica hybrid in 2003 when no-till was compared with broadcast seeding. In 2004, brassica hybrid dominated mixed stands, irrespective of planting method. Some of the differences ob-

[1] Trade names are used for reader convenience and do not imply endorsement by USDA over comparable products or services.

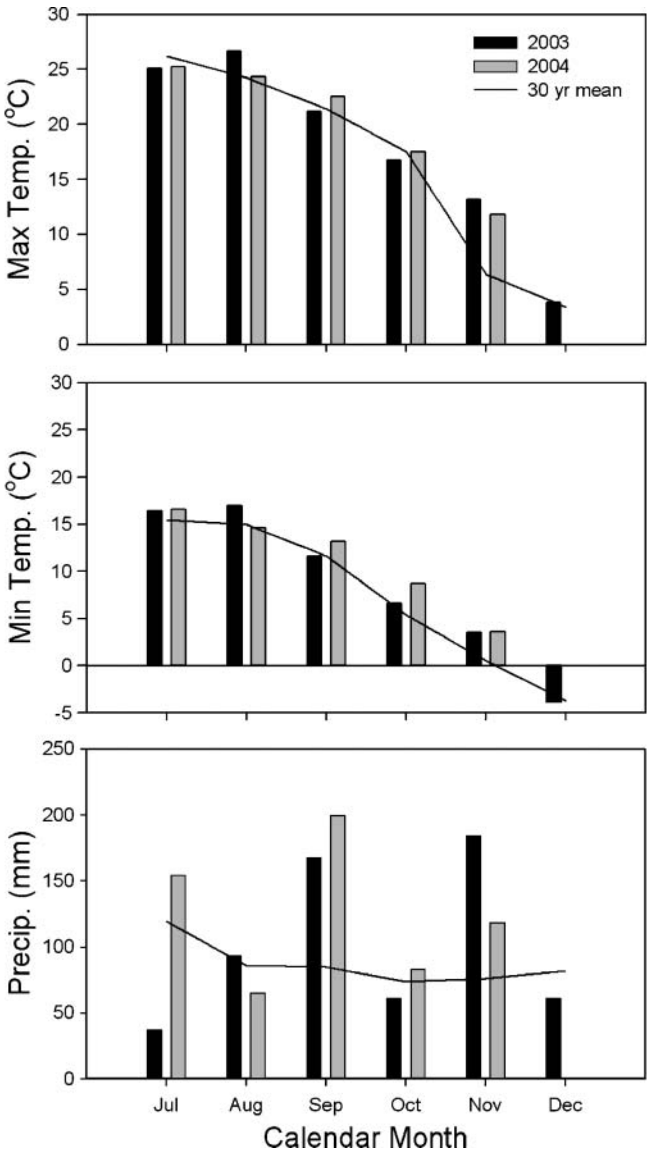

Fig. 1. Monthly and 30-yr mean maximum and minimum air temperatures and precipitation for 2003 and 2004, at Beckley, WV.

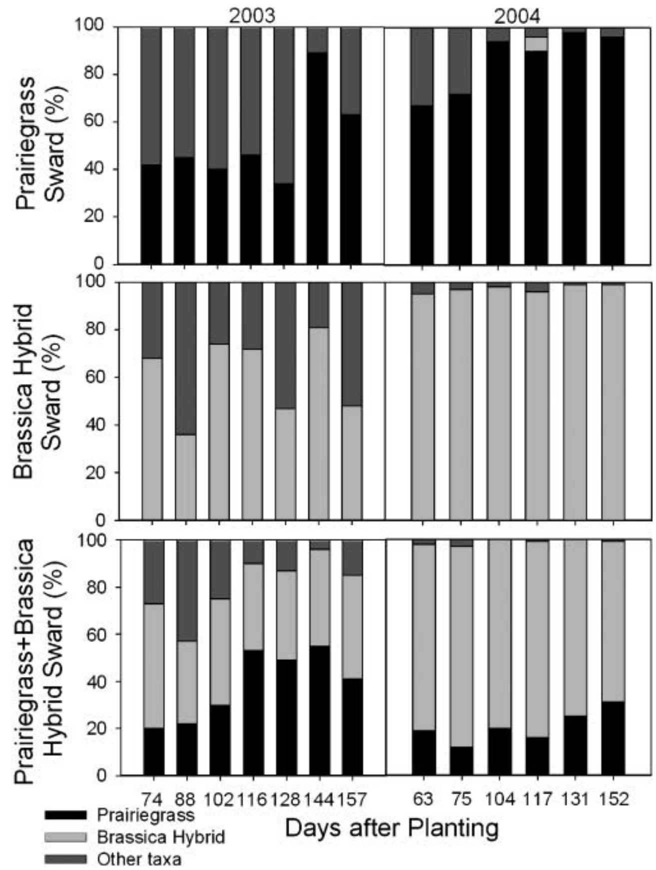

Fig. 2. Botanical composition of prairiegrass, brassica hybrid, and a prairiegrass–brassica hybrid mixture during 2003 and 2004. Values representing the number of contacts (as a percentage) are the mean of three replicates.

served could be associated with the slight, but typical, variations in the seedbed at the time of planting, in addition to differences in growing conditions occurring in a particular year. Also, visual assessment of sward composition patterns were probably influenced by the method used to determine botanical composition.

Table 1. Analysis of variance for stand botanical components (illustrated in Fig. 2) as a function of year (Y), sown species (SS), planting method (PM), and the interactions.

	Stand components					
	Prairiegrass		Brassica hybrid		Other taxa	
	F	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*
Y	2.75	ns†	180.04	***	218.83	***
SS	116.46	***	624.63	***	4.33	ns
PM	11.73	***	27.55	***	5.36	*
Y × SS	68.61	***	42.11	***	8.10	***
Y × PM	11.67	***	0.36	ns	11.74	***
SS × PM	31.85	***	19.53	***	0.72	ns
Y × SS × PM	5.13	**	0.29	ns	1.73	ns

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
† ns, not significant.

Maintaining a predetermined or fixed-stand composition in pasture is difficult. Fluctuations in composition often correlate with weather (Silvertown and Lovett-Doust, 1993; Gerrish and Sanderson, 2000) and management (agronomic and grazing), both of which are influenced by the complex terrain and microsite conditions occurring in hill land. Sward composition influences productivity and distribution of herbage mass in a season although the relationship of productivity and agroecosystem processes associated with sward composition is still very much an unresolved issue (Tilman, 1999).

Herbage Productivity

In our experiment, species density varied as a function of site-specific conditions and the growth habit and patterns of resource acquisition and allocation of each component of the stand over time. Dry matter productivity varied substantially between years ($P < 0.001$). The variation may be attributable in part to fluctuating weather and stand damage caused by selective grazing by white-tail deer (*Odocoileus virginianus*) that occurred each year, but especially in 2003 (Fig. 3). Declining brassica hybrid herbage DM production could arise from

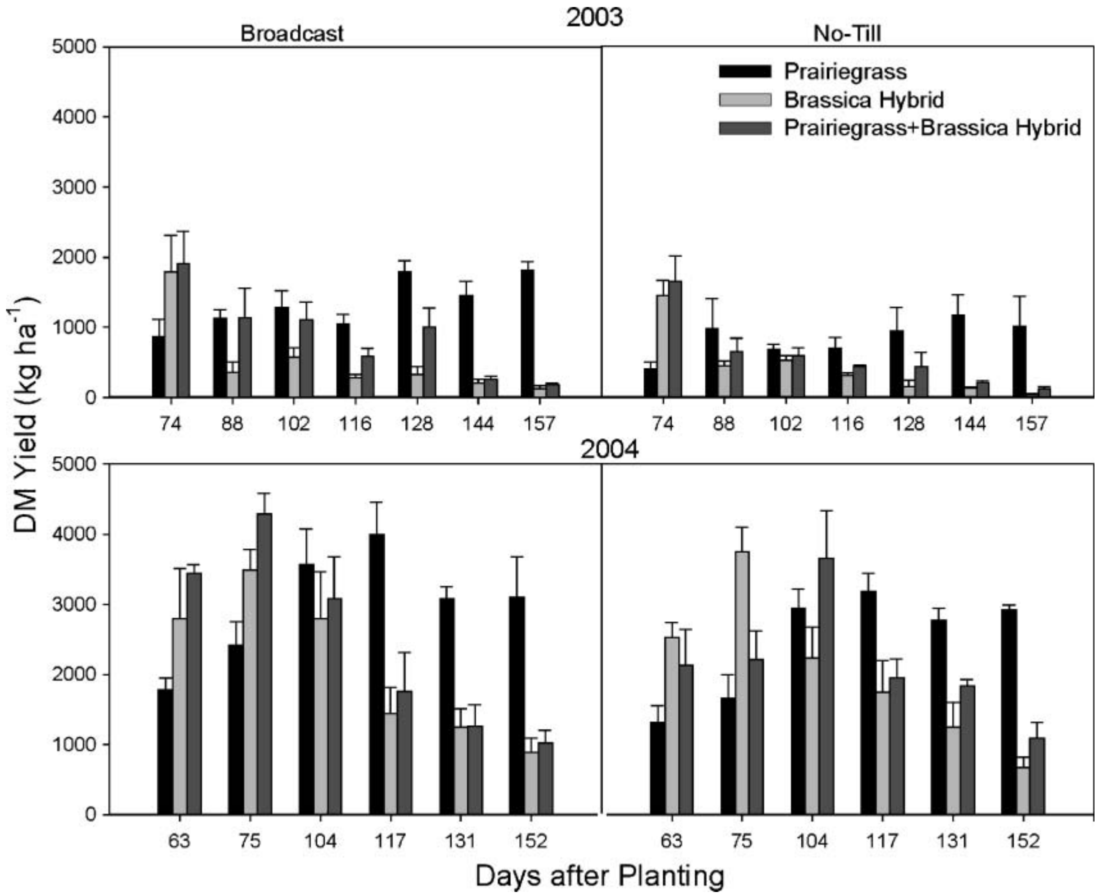

Fig. 3. Seeded species dry matter (DM) yield of prairiegrass, brassica hybrid, and prairiegrass–brassica hybrid mixtures in 2003 and 2004 as a function of planting method. Vertical bars are standard error of the mean.

shifts in photosynthate allocation from aerial herbage to tubers. Precipitation was scarce in July of 2003 and is reflected in relatively greater prairiegrass yields and stand composition compared with brassica hybrid. Ample precipitation after planting occurred in July 2004 and is reflected in relatively greater brassica hybrid presence and productivity. Planting method influenced DM yield of seeded species with a slight increase in productivity for broadcast compared with no-till sown stands ($P < 0.05$).

Total DM yield was influenced by interaction of sown species with harvest date (Table 2) reflected in yield distribution during the season (Fig. 3). Productivity of undisturbed stands of prairiegrass was sustained while that of brassica hybrid declined during the 14-wk interval after the initial harvest in both years. Productivity of brassica hybrid and prairiegrass–brassica hybrid mixed stands was greater early in the growth interval while prairiegrass productivity was greatest and often surpassed that of brassica hybrid or prairiegrass–brassica hybrid mixtures later (Fig. 3). For example, prairiegrass stockpiled for 74 d in 2003 produced 875 kg ha^{-1} while stockpiling for 157 DAP yielded 1800 kg ha^{-1}. Stock-

Table 2. Analysis of variance showing *F* values and significance for the influence of sown species (SS; prairiegrass, brassica hybrid, and prairiegrass–brassica hybrid mixtures), planting method (PM; broadcast or no-till), harvest date (D), and the interactions on dry matter (DM), crude protein (CP), and total nonstructural carbohydrates (TNC) of monospecific and mixed stands of prairiegrass and brassica hybrid in 2003 and 2004.

	2003						2004					
	DM		CP		TNC		DM		CP		TNC	
	F	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*	*F*	*P* > *F*
SS	31.60	***	0.72	ns†	5.59	**	1.20	ns	2.98	*	106.85	***
PM	19.78	***	0.04	ns	11.22	***	0.65	ns	0.47	ns	0.18	ns
D	27.17	***	3.79	**	55.85	***	66.19	***	25.64	***	147.45	***
SS × PM	3.37	*	0.42	ns	5.21	**	0.10	ns	1.26	ns	0.36	ns
SS × D	10.07	***	0.12	ns	2.41	**	4.97	***	0.85	ns	48.88	***
PM × D	1.93	*	0.03	ns	0.99	ns	0.81	ns	0.17	ns	0.77	ns
SS × PM × D	0.61	ns	0.10	ns	0.81	ns	0.97	ns	0.18	ns	1.41	ns

* $P < 0.05$.
** $P < 0.01$.
*** $P < 0.001$.
† ns, not significant.

Table 3. Inflection points (calendar day, with day after planting in parentheses) derived from the Gompertz growth rate model for seeded species DM production when broadcast (B) or no-till (NT) planted.

Seeded species	Planting method	2003	2004
Prairiegrass	B	306 (125)†	282 (102)
	NT	302 (121)	285 (105)
Brassica hybrid	B	267 (86)	261 (81)
	NT	262 (81)	264 (84)
Prairiegrass	B	270 (89)	261 (81)
Brassica hybrid	NT	273 (92)	267 (87)

† Estimate of $dy^2/dx^2 = 0$, where y = day of year (or days after planting) and x = growth rate in kg ha^{-1} d^{-1}.

piling brassica hybrid for 74 d resulted in about 1800 kg ha^{-1}, whereas stockpiling for 152 d produced only 130 kg ha^{-1} in 2003. The trend in productivity was similar for monospecific stands of prairiegrass and brassica hybrid, regardless of planting method and year although yields were much greater in 2004. The DM yield of the mixture exceeded that of brassica only in both years, irrespective of planting method (Fig. 3).

Inflection points, derived from Gompertz growth curve models, represent when maximum growth occurred and show that prairiegrass productivity reached maximum later in 2003 than in 2004 and brassica hybrid or the prairiegrass–brassica hybrid mixtures reached maximum production rates earlier in the growth interval than prairiegrass (Table 3). Brassica hybrid reached maximum rates of growth at about the same time each year (about 20 September each year, or about 85 DAP), with the decline thereafter, probably reflecting a shift in photosynthate allocation from foliage to tuber production. Maximum prairiegrass DM productivity occurred later (5 wk later in 2003 and 3 wk later in 2004) than that of brassica hybrid. This suggests that prairiegrass can help sustain DM productivity for a longer time in the autumn stockpiling interval.

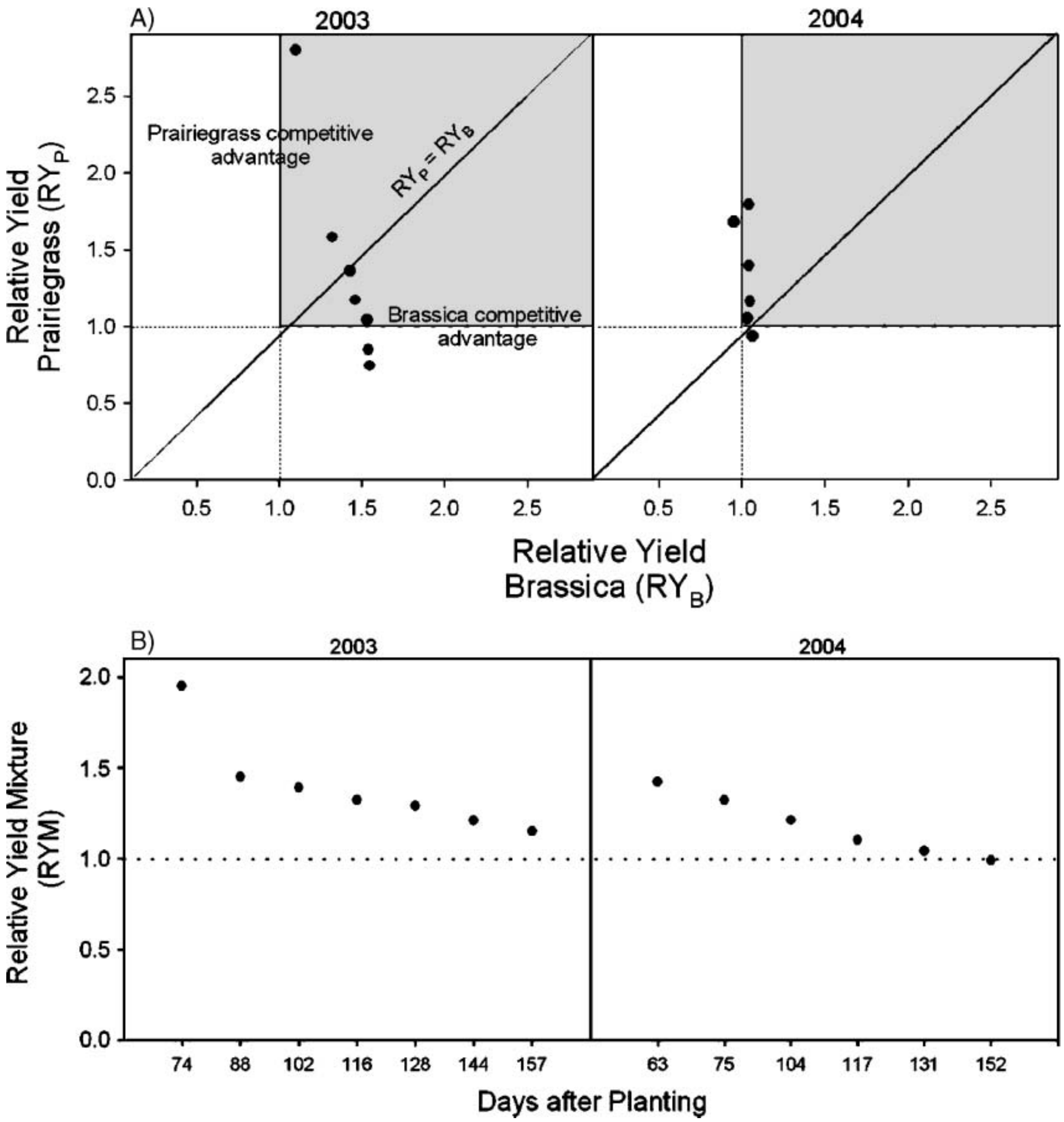

Fig. 4. Mean values for (A) relative yield and (B) relative yield of mixture for prairiegrass–brassica hybrid stands in 2003 and 2004.

Response pattern of mixtures can be assessed with indices such as relative crowding coefficients, aggressivity, or relative yield estimates using any number of response parameters (Trenbath, 1974). Relative yield can relate productivity of a species growing in the presence of another species and, when presented graphically, gives some indication of whether facilitation, suppression, or interference occurs between the components. Relative yields of brassica hybrids tended to be similar within years while those of prairiegrass varied (Fig. 4A). For a given species, a relative yield of 1.0 indicates equilibrium with competing species and conspecifics while values > or < 1.0 suggest competition for resources by a particular component of the mixture (Williams and McCarthy, 2001). Brassica hybrid appeared to have a slight competitive advantage when compared with prairiegrass in 2003, whereas prairiegrass appeared to be somewhat more competitive in 2004 (Fig. 4A). An

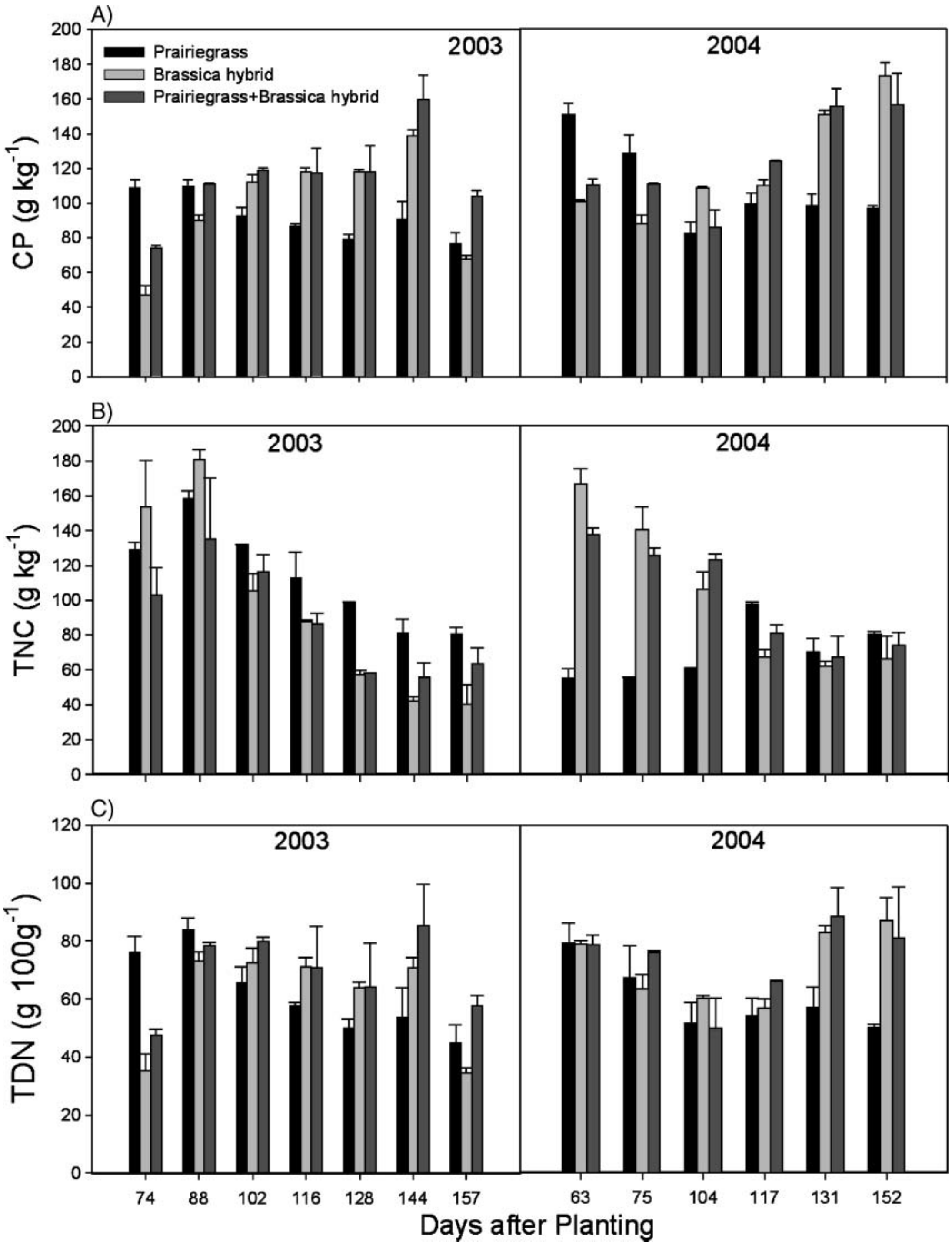

Fig. 5. Mean values for (A) crude protein (CP), (B) total nonstructural carbohydrate (TNC), and (C) total digestible nutrient (TDN) concentrations of prairiegrass, brassica hybrid, and prairiegrass–brassica hybrid mixtures during 2003 and 2004. Vertical bars are standard error of the mean.

exception occurred early in the 2003 growing season when prairiegrass appeared to be a vigorous competitor. Some facilitation occurred (shaded portion of the graph) in both years, suggesting improved productivity by the mixture (Fig. 4A). The RY of brassica hybrid varied in 2003 from 1.1 to 1.5 and was somewhat consistent in 2004 at 1.0 (Fig. 4A). Relative yield of prairiegrass in the presence of brassica hybrid varied, ranging from 0.8 to 2.9 in 2003 and from 0.9 to 1.7 in 2004 (Fig. 4A).

Estimating RYM (Eq. [4]) provides an index of the productivity of a binary mixture relative to that of the component species grown as a monoculture (Fig. 4B). A RYM value equal to 1.0 suggests that species in the mixture are competing for resources, with facilitation occurring where RYM $>$ 1.0 and antagonism when RYM $<$ 1.0 (Silvertown and Lovett-Doust, 1993). The RYM (Fig. 4B) for prairiegrass–brassica hybrid plantings suggests mixtures were more productive than either species growing alone, especially in 2004.

The apparent advantage of prairiegrass–brassica hybrid mixtures in terms of yield distribution could be attributable, in part, to different resource acquisition and use patterns (Wilson, 1988). Superior-yielding mixtures are more likely to occur in natural than controlled environment or artificially structured associations because differing morphological and physiological characteristics provide plants with the ability to access resource patches in different parts of the sward.

Nutritive Value

Forage-based livestock production requires synchronized management of herbage mass and nutritive value to sustain forage production and persistence over time while meeting the nutritional needs of grazers. Stands containing brassica hybrids show good potential for meeting the herbage dry matter intake needs of several grazing livestock species although there is some concern that fiber might be limiting and restrict nutrient use efficiency by growing lambs (*Ovis* spp.) (Guillard et al., 1988). Brassica species grow vigorously and retain nutritive value in autumn; however, the high soluble nutrient content should be balanced with fiber and energy to optimize rumen microbial function and nutrient use by the grazer (Wikse and Gates, 1987; Guillard et al., 1988; Cassida et al., 1994).

Crude protein concentrations varied significantly during the growth interval each year (Table 2). The CP concentrations of prairiegrass declined from about 110 to 75 g CP kg^{-1} in 2003 and from 150 to 80 g CP kg^{-1} during the 2004 growing season (Fig. 5A). Concentrations probably declined because of slower growth and nutrient uptake associated with decreasing light and temperature during the autumn stockpiling interval. The CP concentrations of brassica hybrid and the prairiegrass–brassica hybrid mixture were somewhat similar throughout the growth interval, ranging from a low of about 50 g CP kg^{-1} in 2003 to a high of 170 g CP kg^{-1} in 2004 for brassica hybrid (Fig. 5A). Concentrations less than 100 g kg^{-1} would be considered CP limiting from a rumen function and animal requirement standpoint.

The TNC concentrations were influenced by interaction of seeded species and harvest date (Table 2). Brassica hybrid TNC declined from about 180 to 40 g TNC kg^{-1} in 2003 and from 170 to 40 g TNC kg^{-1} in 2004. Prairiegrass TNC declined about 50% in 2003 and increased slightly during 2004 (Fig. 5B). Mixtures were intermediate in TNC when compared with monospecific stands of either brassica hybrid or prairiegrass and reflect TNC concentrations of individual components of the sward.

Brassica hybrid TDN declined from about 70 to 35 g TDN 100 g^{-1} in 2003 and from 90 to 60 g TDN 100 g^{-1} in 2004, and prairiegrass declined from a season high of about 85 g 100 g^{-1} to about 50 g 100 g^{-1} in 2003 and 2004 (Fig. 5C). Mixtures generally were equivalent to or superior in TDN when compared with monospecific stands of either brassica hybrid or prairiegrass and reflect TDN concentrations of individual components of the sward. The TDN values for brassica hybrid reflect

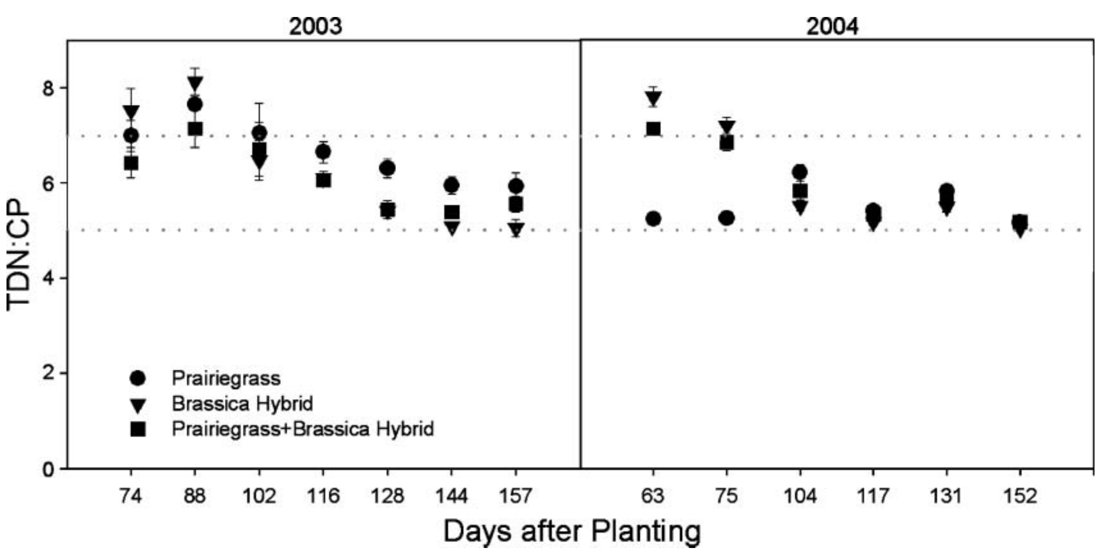

Fig. 6. Mean values for total digestible nutrient (TDN):crude protein (CP) quotients of stockpiled herbage of prairiegrass, brassica hybrid, and a prairiegrass–brassica hybrid in 2003 and 2004. Vertical bars are standard error of the mean.

the effects of seasonal weather conditions on herbage nutritive value (Wiedenhoeft and Barton, 1994), with relatively low TDN early in the 2003 growing season when precipitation was limited and improving as temperatures moderated and precipitation occurred in autumn (Fig. 5C). Changes in CP, TNC, and TDN reflect influences of season and sward composition.

Energy requirements of rumen microorganisms might not be met, nor those of the grazer, when large amounts of herbage N are present relative to carbohydrate (Wallace and Cotta, 1988). Conversely, fiber energy (which depends on microbial activity for release) is not available when N is deficient. An imbalance in energy relative to crude protein could lead to inefficient protein utilization and N loss.

The TDN:CP quotient provides an indication of energy and N balance (Belesky et al., 2006). Based on microbial and animal requirements, TDN:CP occurring in the range of 5 to 7 indicates neither excess nor inadequate N relative to a given amount of available energy. It does not, however, provide any insight into actual levels or whether requirements are met. For example, forage with TDN of 30 and CP of 5 would have an "ideal" TDN:CP of 6 but essentially would be useless to the animal. A forage with TDN of 80 and CP of 30 (TDN:CP of 2.7) would support high levels of production in many classes of livestock based on energy estimates. The imbalance of N relative to energy would lead to inefficient N utilization and negative energy balance. Expressing nutritive value as TDN:CP (Fig. 6) showed values generally occurring within the 5 to 7 range and could be considered satisfactory for rumen microbe activity and grazing animal response. The TDN:CP values tended to exceed 7 in early harvests when TNC concentrations were relatively high (Fig. 5B).

The TNC:CP quotient (data not shown) of brassica hybrid and the prairiegrass–brassica hybrid mixture differed with years ($P < 0.001$) and tended to decline with time each year. The decline reflected changes in stand composition during the growth interval and provides an index of nutritive value in swards containing cool-temperate-origin forages (Belesky et al., 2005). The

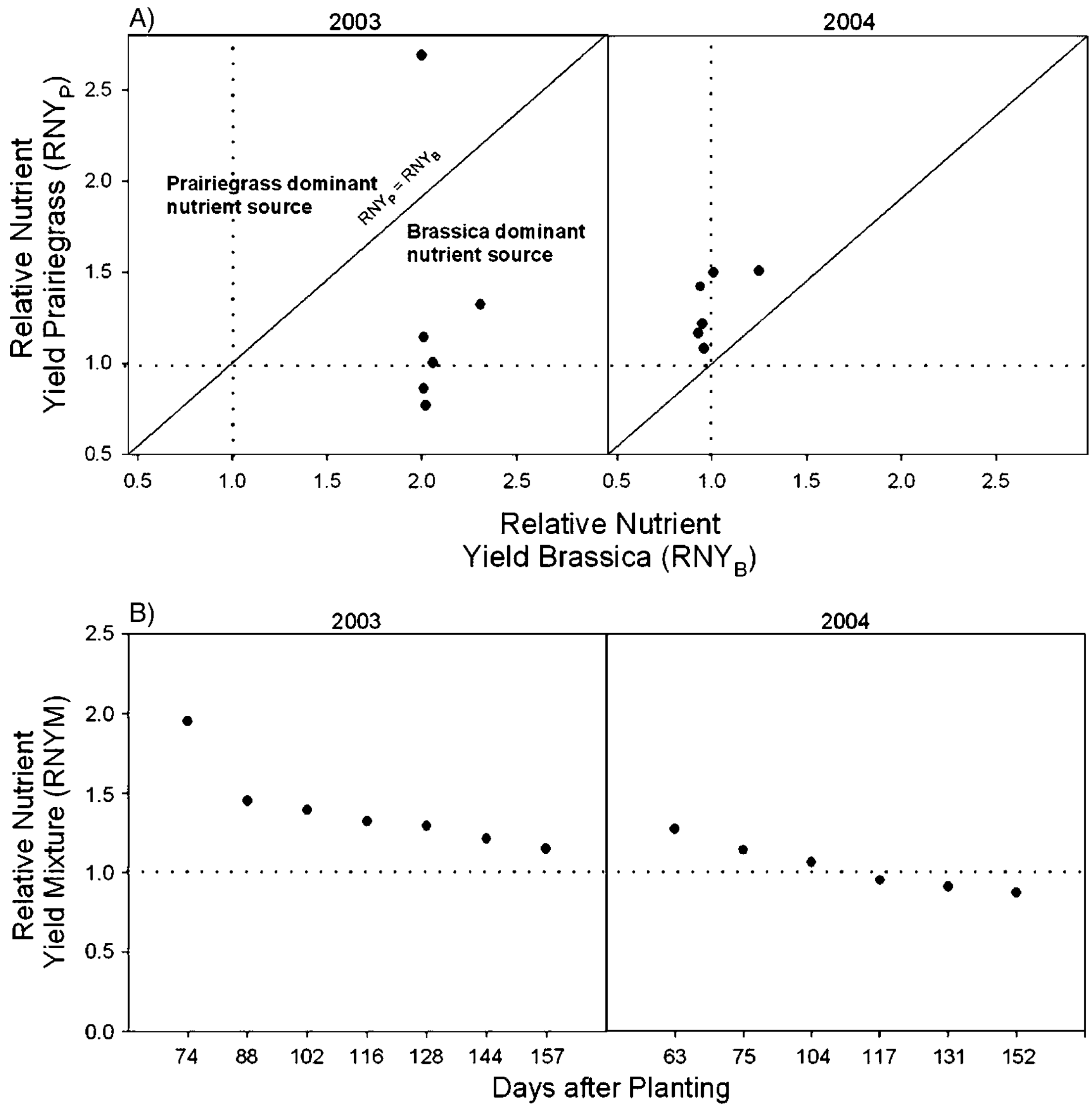

Fig. 7. Mean values for (A) relative nutrient yield and (B) relative nutrient yield of mixture for prairiegrass–brassica hybrid stands in 2003 and 2004.

TNC-based index is relevant to livestock needs since readily available energy determines intake (Forbes, 1986) and grazer preference (Burns et al., 2001), and TDN:CP can be predicted from the index with much less time and expense. Values were comparable to those for orchardgrass growing under similar conditions (Belesky et al., 2006).

We applied the relative yield model to TDN data to determine how individual components sown in mixture contributed to available herbage nutritive value and how nutritive value was related to herbage mass (expressed as relative nutrient yield in Fig. 7A). Values greater than $RNY_P = RNY_B$ suggest that prairiegrass was the dominant source of nutritive value, and lesser values indicate brassica hybrid as the primary nutrient contributor. Brassica hybrid was the dominant nutrient source in 2003, whereas prairiegrass was in 2004 (Fig. 7A). When brassica hybrid dominated production, the relative nutrient yield was stable, reflecting in vitro dry matter disappearance patterns reported by Jung et al. (1986) for autumn-grown brassica forage. Relative nutrient yield of mixtures (Fig. 7B) suggest that prairiegrass–brassica hybrid mixtures provided superior herbage nutritive value in both years, with clear benefit attributable to the mixture throughout 2003 and a slight benefit early in the 2004 growth interval.

Prairiegrass can be co-established with brassica hybrid, contributing to supply and improving nutritive value of herbage in autumn. Herbage can be harvested in the establishment year, without compromising prairiegrass persistence in subsequent years (data not shown). Prairiegrass increased as a percentage of sward composition in mixed stands. Stand composition and herbage productivity differed between years, probably because of precipitation patterns. Patterns of herbage productivity differed during the growing season. Productivity of brassica hybrid herbage was greatest early and declined later, whereas that of prairiegrass reached maximum later and remained steady during much of the growth interval. Nutritive value of mixed stands was within a range recommended for growing beef cattle throughout the growth interval. The seasonal distribution patterns argue in favor of prairiegrass or mixtures including prairiegrass where production stability rather than greater herbage quantity is a goal. A mixed stand of prairiegrass–brassica hybrid appeared to be beneficial in terms of productivity and nutritive value when there was adequate and well-distributed precipitation.

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